A First View of Temperature Fields from the Microwave Limb Sounder on Aura

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http://mls.jpl.nasa.gov

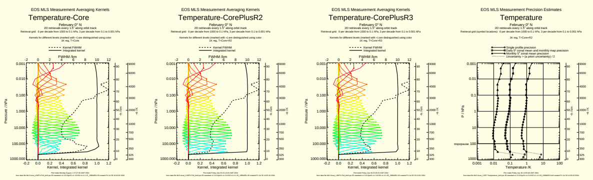
1 Abstract

A second-generation Microwave Limb Sounder (MLS) was launched in July of 2004 as a part of the Earth Observing System (EOS) Aura satellite. This instrument provides temperature fields co-located with atmospheric composition measurements from the upper troposphere through the mesosphere. In this poster we give an overview of the MLS temperature measurements from the first months of EOS Aura observations. Of particular interest is the 3-dimensional evolution of temperatures in the Antarctic polar vortex during the late winter and spring final warming, including the evolution of temperatures in the lower stratosphere associated with polar processing, and planetary wave evolution during vortex breakup.

2 MLS Temperature Retrieval

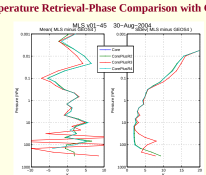
- MLS retrievals are broken into several "phases," each of which has an associated temperature product. This approach allows for better consideration of the radiance error budget than the more usual "constrained quantity error" propagation.
  - "Core" Temperature is based only upon the 118-GHz R1 radiometer and has the poorest vertical resolution but is least prone to retrieval instability.
  - "CorePlusR2", "CorePlusR3", "CorePlusR4" and "CorePlusR5" retrievals add 190-GHz (R2), 240-GHz (R3), 640-GHz (R4) and 2500-GHz (R5) radiances respectively. The v01.45 and v01.46 CorePlusR2 and CorePlusR3 products are prone to oscillation due to inaccuracies in the modeling of R2 and R3 radiances in these early ("launch-ready") versions of the algorithms.
- Retrieval performance is significantly improved in v01.50, which will be used in production processing starting in January of 2005, and will yield the first "public" MLS dataset.
- Maps and time-series plots on this poster are based upon (the similar) v01.45 and v01.46 "Core" temperatures, as few days have yet been processed with v01.50.

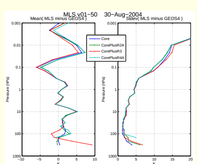
2.1 Vertical Averaging Kernels and Precision



- The first three plots show modeled averaging kernels for three MLS v01.50 temperature products. Each product is a retrieval on 28 surfaces, 6 surfaces-per-decade from 316 hPa to 0.1 hPa and on 3 surfaces-per-decade from 0.1 hPa to 0.001 hPa.
- Dashed lines are the FWHM of the averaging kernels. The FWHM of the "Core" averaging kernels is 6 km at 1 hPa, improves to 4 km between 10 hPa and 32 hPa but degrades to 6 K at 100 hPa and 8 K at 147 hPa.
- "CorePlusR2" averaging kernels have FWHM of approximately 4 km through the upper troposphere and lower stratosphere and are similar to those of "Core" higher in the atmosphere.
- The fourth plot shows single-profile precision for CorePlusR2 (right-most line) and the same line scaled to approximate daily and monthly-averaged values. Precision for Core, CorePlusR2 and CorePlusR3 is similar (better than 1 K) in the stratosphere and above. "Core" precision degrades in the troposphere to 2 K at 316 hPa, but "Core" has smaller biases relative to GMAO GEOS-4 than the other phases. "CorePlusR2" temperature has precision of 0.9 K at 316 hPa.

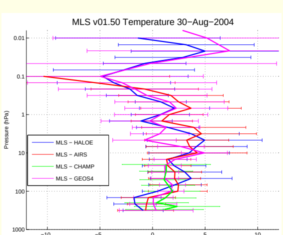
2.2 Temperature Retrieval-Phase Comparison with GMAO GEOS-4





- The "launch-ready" v01.45 and v01.46 "CorePlusR3" temperature displays large, persistent vertical oscillations in the upper troposphere and lower stratosphere, and smaller oscillation are present in "CorePlusR2" temperatures. Retrieval stability is significantly improved in v01.50, which will be the production software starting in January of 2005, but CorePlusR3 still swings from a -2.5 K bias w.r.t GEOS-4 at 100 hPa to a +9 K bias at 316 hPa.

2.3 Comparison of MLS v1.5 Temperature Profiles with AIRS, HALOE and CHAMP GPS

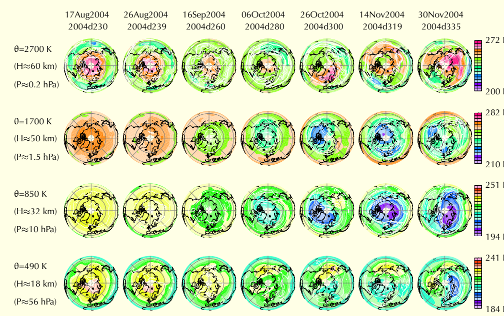


- Plots show MLS minus AIRS (IR on Aqua), HALOE (solar IR occultation on UARS), CHAMP (GPS occultation) and GMAO GEOS-4 (NASA Global Modeling and Assimilation Office assimilation.) Error bars are the scatter of the profile comparisons. The MLS temperature used is v1.5 "Core" 316 hPa to 1 hPa and "CorePlusR2" above.
- In the upper troposphere, MLS is 2 K cooler than HALOE and 1-2 K warmer than CHAMP. Agreement is better than 1 K with GEOS-4 and AIRS.
- In the lower stratosphere (100-14.7 hPa), MLS is 1-2 K warmer than CHAMP and GEOS-4 and 2.5 K warmer than AIRS. HALOE varies from 0-4 K cooler than MLS.
- MLS is 4-5 K warmer than the other sets at 10 hPa. In the comparison with GEOS-4, this is a sharp feature in altitude, while with respect to AIRS and HALOE, large biases continue into the upper stratosphere.
- Agreement is to ± 1 K at 1.47 hPa, then MLS swings back and forth with respect to HALOE and GEOS-4. MLS is: 2 K warm at 0.68 hPa, 5 K cold at 0.1 hPa and 5-7 K warm at 0.0215 hPa.

3 Maps of MLS Temperature on Isentropic Surfaces

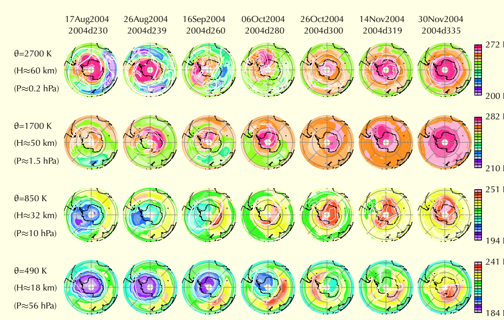
- Maps show MLS v01.45 and v01.46 "Core" temperature on isentropic surfaces for seven days at roughly 20-day spacings.
- Three potential vorticity contours from the GEOS-4 analysis are shown in white. When closely-spaced and concentric, they mark the polar vortex edge. Cold regions are not confined in the vortex in the way that atmospheric constituents are, but low temperatures do develop in the confined air mass of the vortex.
- Maps of temperature on isentropic surfaces show the temperatures through which air parcels can move adiabatically.

3.1 Northern Hemisphere



- Low temperatures are associated with the northern polar vortex on the 1700 K and 850 K isentropic surface as it spins up through October.
- On the 490 K isentropic surface, the region of low temperatures associated with the vortex only begins to become apparent in the 30-Nov map.
- Planetary wave activity disturbs the symmetry of the northern vortex at all times, as is characteristic of northern fall and winter.

3.2 Southern Hemisphere

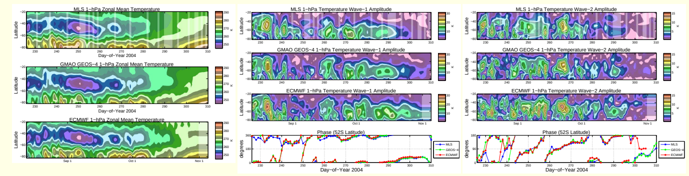


- The southern vortex erodes from the top of the atmosphere downward, so winter-like low temperatures associated with the vortex persist through October on the 490-K isentropic surface. High temperatures are already present over the pole at the beginning of the time-series on the 1700-K isentropic surface.
- The high temperatures move over the poles before the vortex breaks up, as is demonstrated by persisting, strong PV gradients.
- On the mesospheric 2700-K isentropic surface, there is strong mid-latitude wave activity in August, primarily wave-1 on August 17 and wave-2 on August 26.

4 Comparison of MLS, GEOS-4 and ECMWF Zonal Means and Planetary Waves

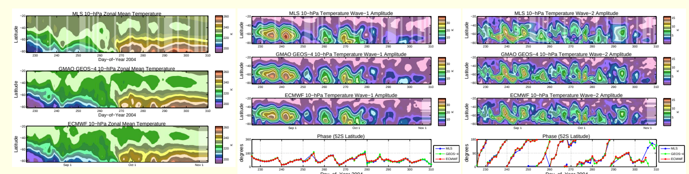
- Data are interpolated to daily maps on uniform lat/lon grids and then zonal means and Fourier components along individual latitudes are calculated.
- Plots are linearly interpolated to provide a smoothed image. Points within days without data are marked with lighter colors.
- Line plots show phase (the longitude at which a wave peaks) for the wave at 52S latitude. Agreement between the analyses' phases and that of MLS is generally within 10°. The most obvious discrepancies are due to phase-unwrapping problems associated with missing MLS data.
- Talks by Manney et al., Santee et al. in session A23F (Tuesday) provide more detailed description of MLS observation of the southern polar vortex and associated chemistry and dynamics.
- Planetary wave activity is associated with the erosion and eventual breakup of the polar vortex. Wave-1 involves a shifting of the vortex off of the pole, resulting in one cycle around the globe, while wave-2 involves a distortion of the vortex.

4.1 1-hPa Zonal Mean, and Wave-1, Wave-2 amplitudes



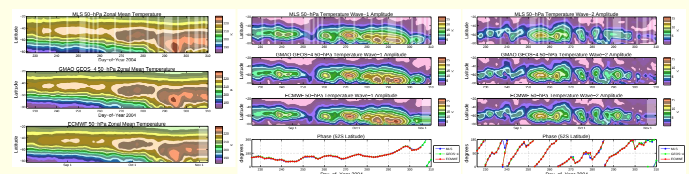
- Zonal mean temperatures at 1-hPa are in as good agreement with the GEOS-4 and ECMWF analyses as the analyses are with one another. The analyses become more poorly constrained by data at these levels and higher, so MLS has the potential to contribute significantly to our knowledge of mesospheric temperatures.
- The lowest temperatures in upper stratosphere are already off the pole by the beginning of this time-series.
- Temperatures in the 40S-60S are lowest when not disturbed by wave-1. The late September wave-1 amplification is during final stages of vortex breakup in the upper stratosphere. The vortex is gone at this level by the beginning of October (2004d275).
- The MLS peak wave-1 amplitude, 2004d232 (Aug 19), is between that of GEOS-4 and ECMWF.
- MLS misses some of the rapidly evolving wave features during mid-September (ed 2004d255) because of gaps in the MLS dataset. Some of these gaps will be filled in during reprocessing.
- The wave-1 amplification in late September is associated with the final breakup of the vortex in the stratosphere.

4.2 10-hPa Zonal Mean, and Wave-1, Wave-2 amplitudes



- MLS zonal mean v01.46 temperatures have a 3-5 K high bias at 10 hPa. Profile comparisons with GEOS-4 show this bias to be confined to a narrow altitude range.
- The vortex is essentially gone in mid-stratosphere (10 hPa) by the end of October (2004d304).
- Wave morphology is very similar among the three datasets. The biggest differences between the images are the result of missing MLS data.

4.3 50-hPa Zonal Mean, and Wave-1, Wave-2 amplitudes



- MLS 50-hPa zonal-mean temperatures have a 2-3 K high bias relative to GEOS-4 and ECMWF but the morphologies of the three datasets are very similar.
- There is a distinct anti-correlation between wave-1 and wave-2. Such an anti-correlation is often associated with non-linear wave-wave interaction.
- Low temperatures are at the pole until mid-October, at which point summer-like conditions prevail, with high temperatures at the pole. The vortex persists into December although there is no associated pool of low temperatures at 50 hPa beyond the end of October.

5 Conclusions

- MLS v01.50 temperature, which will be the initial publicly-released temperature data product, appears to have a warm bias in the stratosphere of from 1-4 K, depending upon the level and the product with which comparison is done. Validation activity is just beginning, so this result should be considered preliminary.
- MLS v01.45 and v01.46 temperatures had larger biases relative to the validation sets examined, but still provide a view of temperature morphology, in association with polar processes, that is consistent with ECMWF and GEOS-4. Agreement between MLS and ECMWF or GEOS-4 is generally about as good as the agreement between ECMWF and GEOS-4.
- Reduction of biases in troposphere and stratosphere and development of a higher-vertical-resolution product for the upper-troposphere/lower-stratosphere is a priority.
- Validation of the mesospheric and lower-thermospheric retrieval (to 0.0001 hPa ≈ 96 km) will begin soon.